RAPID REFRESH (RAP)
Upgrade V2.0.0

EMC Change Configuration Board

January 10, 2013

Presented by: Geoff Manikin, Stan Benjamin
Collaborators:
Steve Weygandt, Ming Hu,
Curtis Alexander, Tanya Smirnova, John Brown,
and the rest of the ESRL/GSD crew

Background

- RAPv2 crash at 18z 26 Dec 2013 in both RAP-NCOpara and RAP-ESRL-primary
- Crash linked definitively to inadvertent change in RAPv2 of hypsometric_opt parameter in WRF
- Hypsometric_opt identifies method to recalculate pressure field via hypsometric integration (1= use pressure, 2= use log p)
- RAPv1 (and WRFv3.2) uses hypsometric_opt=1 (embedded within code). WRFv3.4 (used in RAPv2) switched default to an alternative integration method (value=2)
  - Discovered Sunday 29 Dec 2013 as part of investigation for 26 Dec crash case.
- Subsequent reruns of previous Greenland and Colombia RAPv2 crash cases with hypsometric_opt=1 were all successful without any terrain elevation changes.
- *Late breaking news*: 8 Jan 2014: NCAR discovered a bug in code for hypsometric_opt=2 after discussions with GSD on this crash. Dry mass state for heights from *initial* conditions was being used at subsequent times, forcing erroneous heights near boundary. This explains why the lateral boundaries showed noise in height fields when strong waves are moving into or out of domain.
- Version of RAPv2 running at NCO since Mon 30 Dec is with hypsometric_opt=1, retaining same terrain with smoothed terrain elevation near boundary. GSD has done all of its testing with this same version (bottom line: crash free for all previous crash tests, better results near RAP lateral boundary, little change over CONUS and Alaska).

- **Why was RAP vulnerable to this problem while other ARW models weren't?**

1. RAP has data assimilation cycling, SREF and HRW are essentially cold-start runs with ARW.
2. RAP runs 6x more frequently, and itself only has crashes about once per 700-1000 events overall.

What has been done after cause isolated

- GSD parallel real-time runs to allow comparisons
  - changed its RAPv2-primary to match the corrected RAPv2-NCOpara with hypsometric_opt=1
  - Changed its RAP-dev1 to intentionally use the erroneous opt=2 value
- GSD retrospective runs
  - GSD ran restarted its winter and summer retro runs with new opt=1 change to allow some statistics.
  - Zeus in very heavy load (extra GFDL runs),
    - winter results for 5 verification times (2.5 days)
    - Summer results for 8 verification times (4 days)
    - Still allowed some credible results

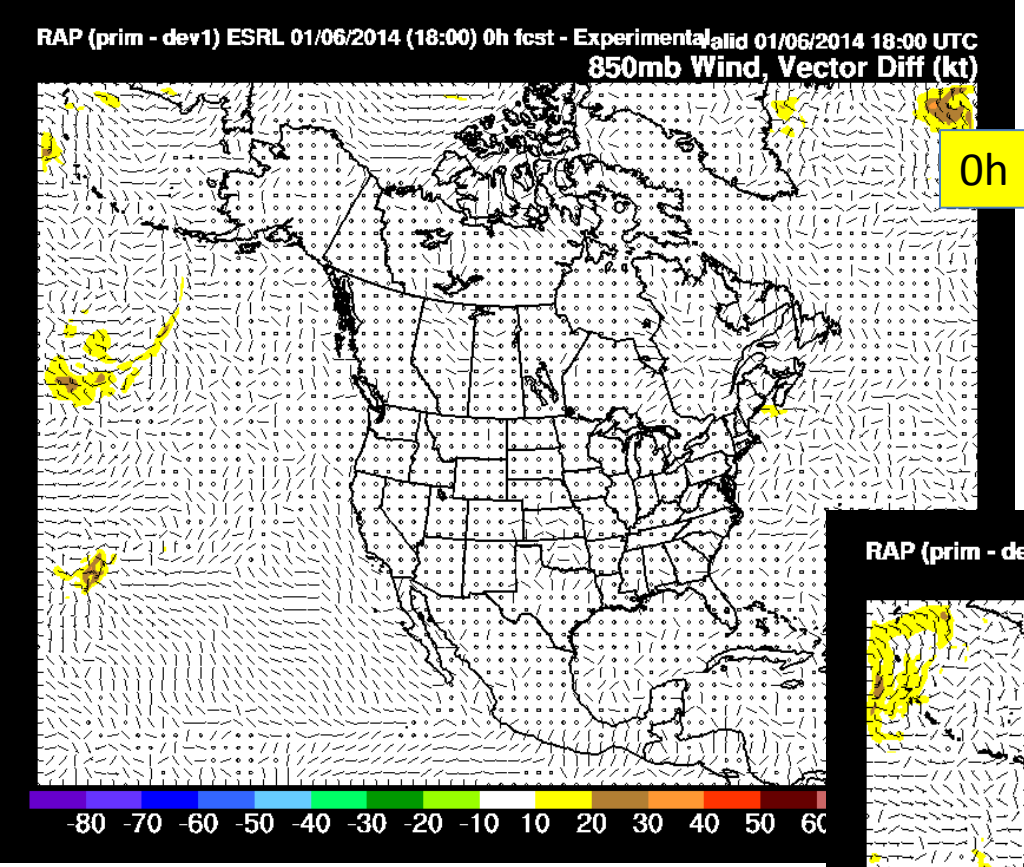
WRFV3.4.1/…./share/dfi.F

Red – incorrect, blue – corrected. Change affects lateral boundary conditions and not just within DFI process. Affects only near boundary values.

```
3450          !  This is the hydrostatic equation used in the model after the small timesteps.  In
3451          !  the model, grid%al (inverse density) is computed from the geopotential.
3452
3453          IF (grid%hypsometric_opt == 1) THEN
3454            DO k  = 2,kte
3455              grid%ph_2(i,k,j) = grid%ph_2(i,k-1,j) - &
3456                        grid%dnw(k-1) * ( (grid%mub(i,j)+grid%mu_2(i,j))*grid%al(i,k-1,j) &
3457                      + grid%mu_2(i,j)*grid%alb(i,k-1,j) )
3458              grid%ph0(i,k,j) = grid%ph_2(i,k,j) + grid%phb(i,k,j)
3459            END DO
3460          ELSE IF (grid%hypsometric_opt == 2) THEN
3461           ! Alternative hydrostatic eq.: dZ = -al*p*dLOG(p), where p is
3462           ! dry pressure.
3463           ! Note that al*p approximates Rd*T and dLOG(p) does z.
3464           ! Here T varies mostly linear with z, the first-order
3465           ! integration produces better result.
3466
3467             grid%ph_2(i,1,j) = grid%phb(i,1,j)
3468             DO k = 2,kte
3469 !             pfu = grid%mu0(i,j)*grid%znw(k)   + grid%p_top
3470 !             pfd = grid%mu0(i,j)*grid%znw(k-1) + grid%p_top
3471 !             phm = grid%mu0(i,j)*grid%znu(k-1) + grid%p_top
3472              pfu = ( grid%mub(i,j)+grid%mu_2(i,j))*grid%znw(k)   + grid%p_top
3473              pfd = ( grid%mub(i,j)+grid%mu_2(i,j))*grid%znw(k-1) + grid%p_top
3474              phm = ( grid%mub(i,j)+grid%mu_2(i,j))*grid%znu(k-1) + grid%p_top
3475              grid%ph_2(i,k,j) = grid%ph_2(i,k-1,j) + grid%alt(i,k-1,j)*phm*LOG(pfd/pfu)
3476            END DO
3477
3478            DO k = 1,kte
3479              grid%ph_2(i,k,j) = grid%ph_2(i,k,j) - grid%phb(i,k,j)
3480            END DO
3481
3482          END IF
```

WRF Change Process

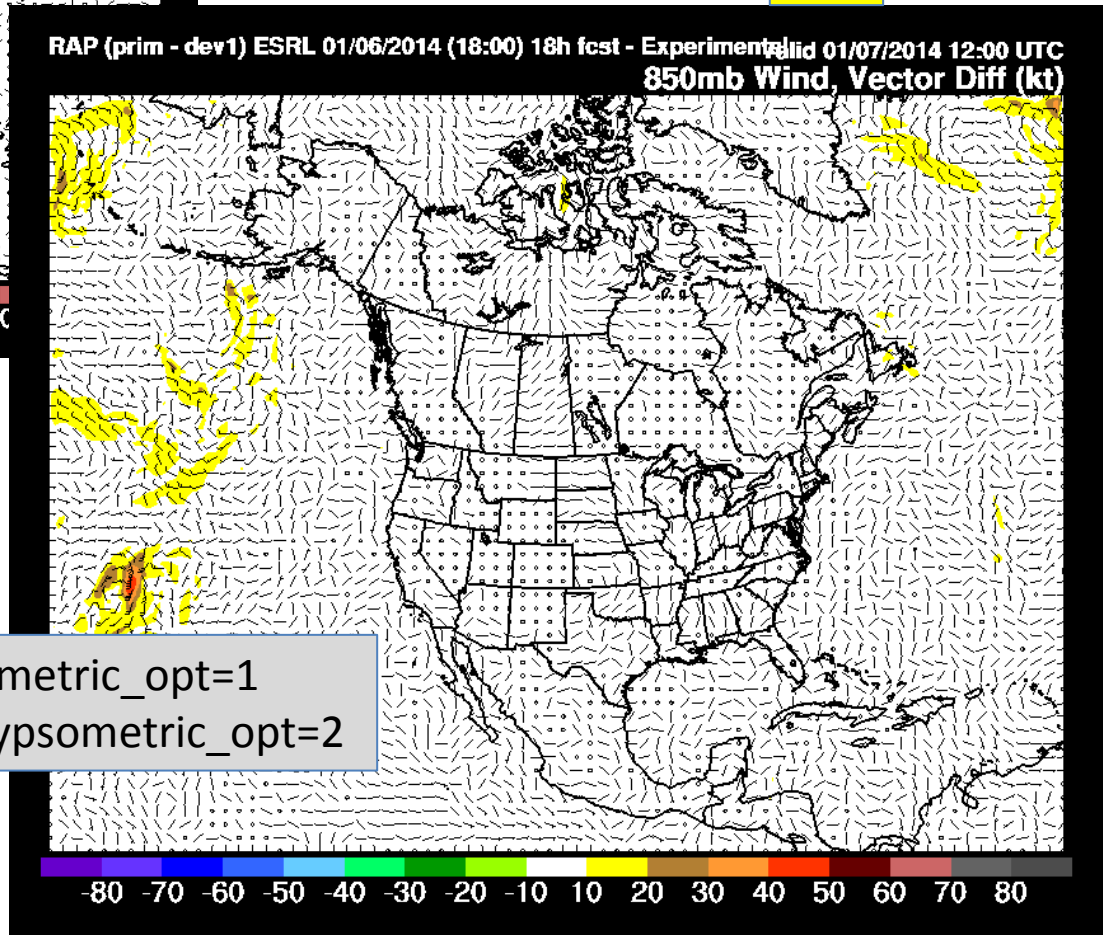
- WRF review committee with membership from NCAR, AFWA, ESRL, and perhaps other labs.
- WRF developer meeting held every Friday morning, including finalization of annual new WRF releases
- WRF testing and evaluation process described in http://www.wrf-model.org/users/testing.php



0h

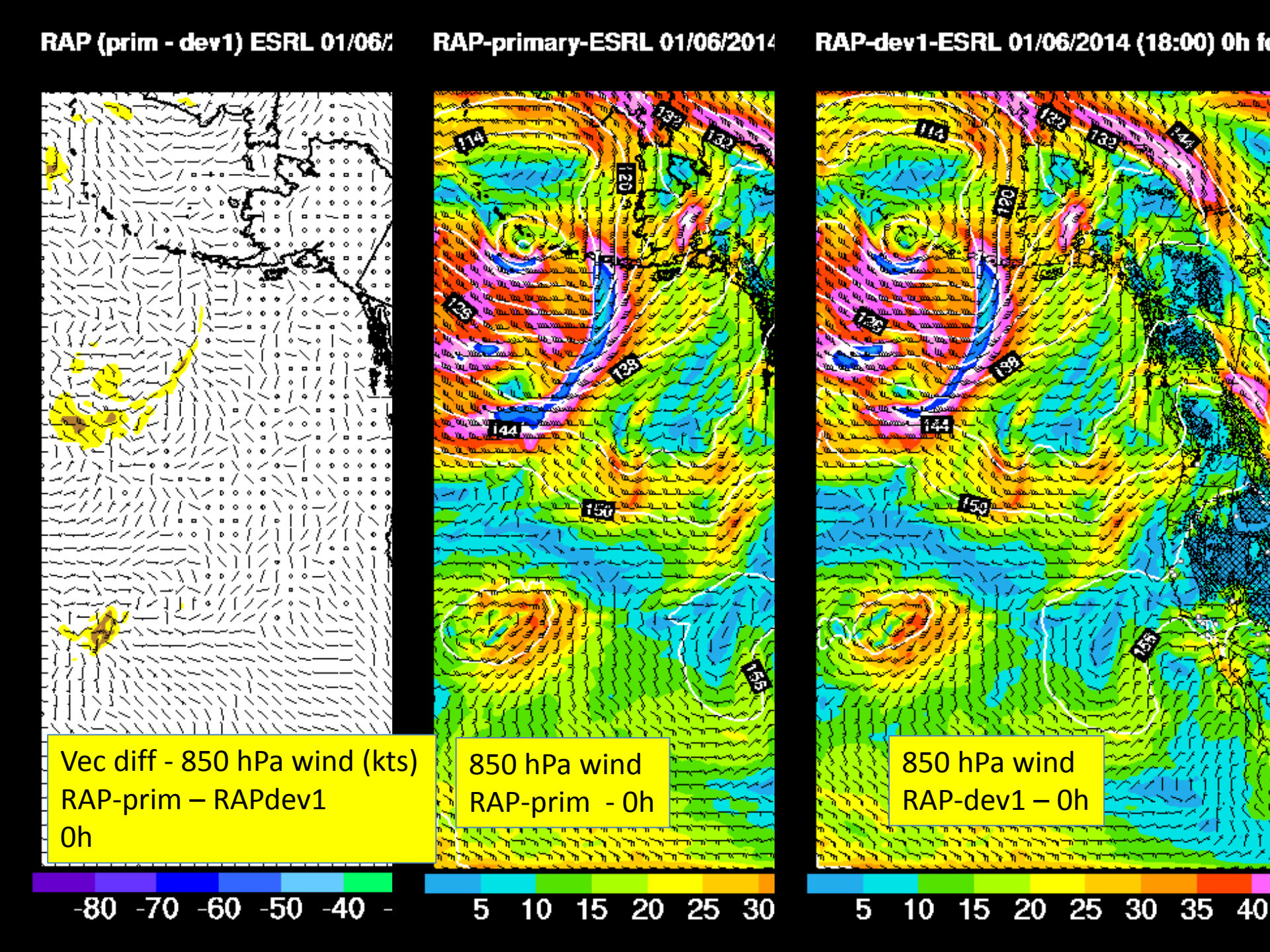
Typical difference from changing from opt=2 to opt=1

18h

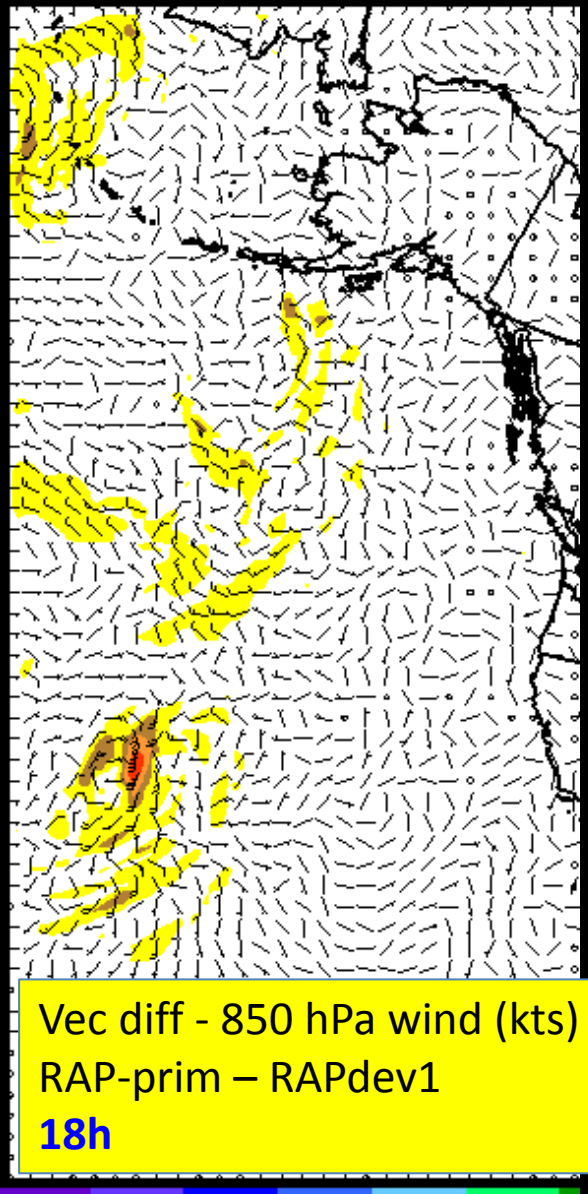


Vector diff - 850 hPa wind (kts)
RAP-prim – RAPdev1

RAP-primary – corrected version – hypsometric_opt=1
RAP-dev1 – boundary contamination – hypsometric_opt=2


RAP (prim - dev1) ESRL 01/06/
RAP-primary-ESRL 01/06/2014
RAP-dev1-ESRL 01/06/2014 (18:00) 0h fc
Vec diff - 850 hPa wind (kts)
RAP-prim – RAPdev1
0h
-80 -70 -60 -50 -40 -
850 hPa wind
RAP-prim - 0h
5 10 15 20 25 30
850 hPa wind
RAP-dev1 – 0h
5 10 15 20 25 30 35 40

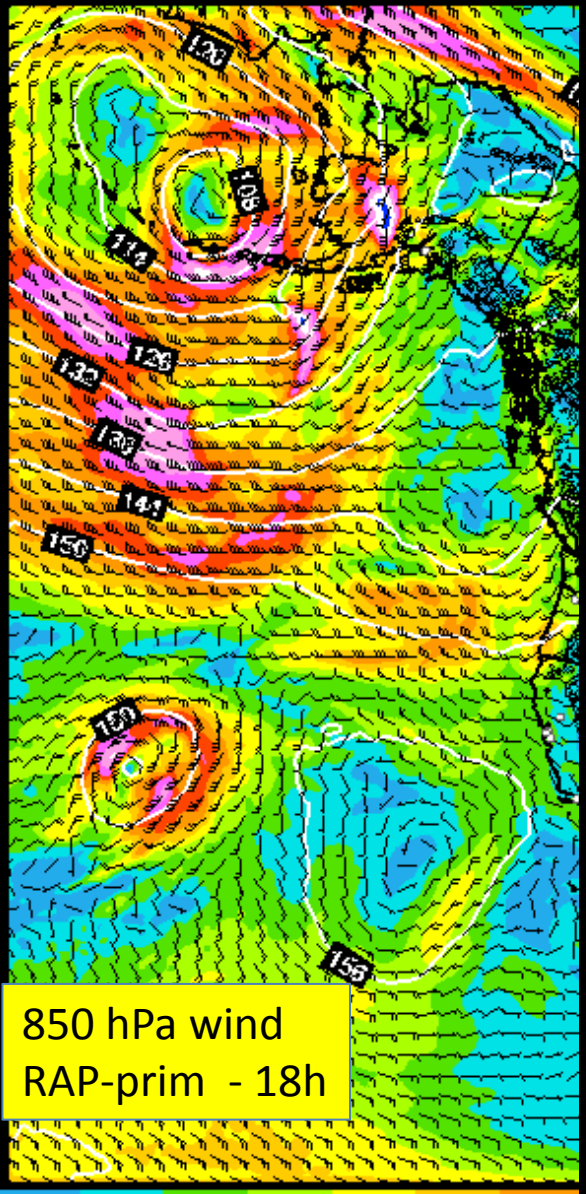
RAP (prim - dev1) ESRL 01/06/20



Vec diff - 850 hPa wind (kts)
RAP-prim – RAPdev1
18h

-80 -70 -60 -50 -40 -3(

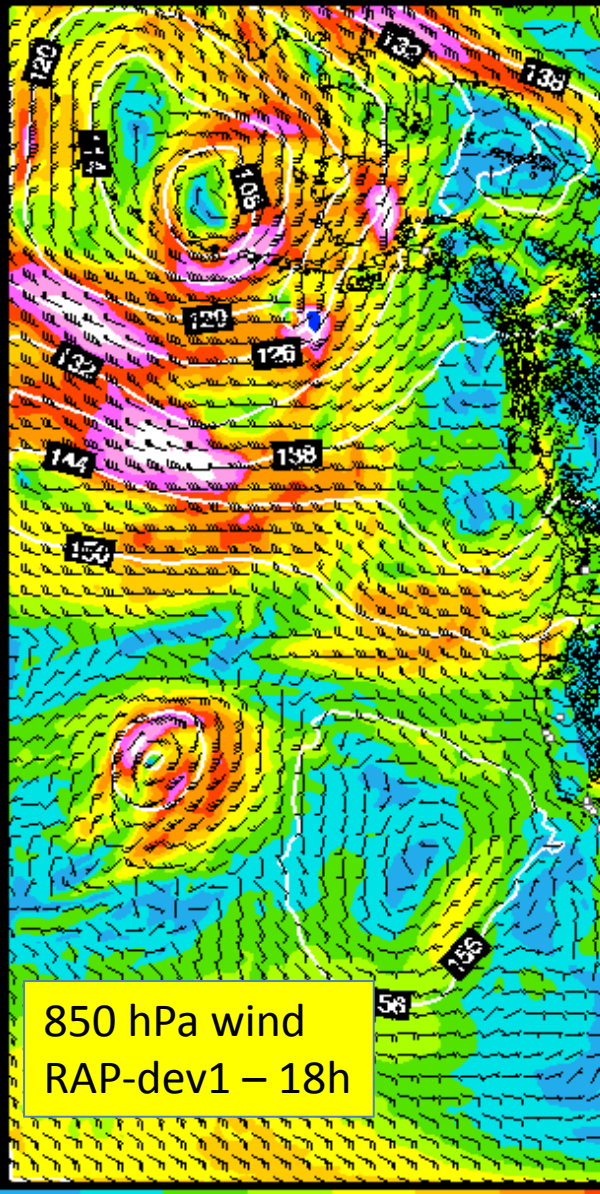
RAP-primary-ESRL 01/06/2014 (1



850 hPa wind
RAP-prim - 18h

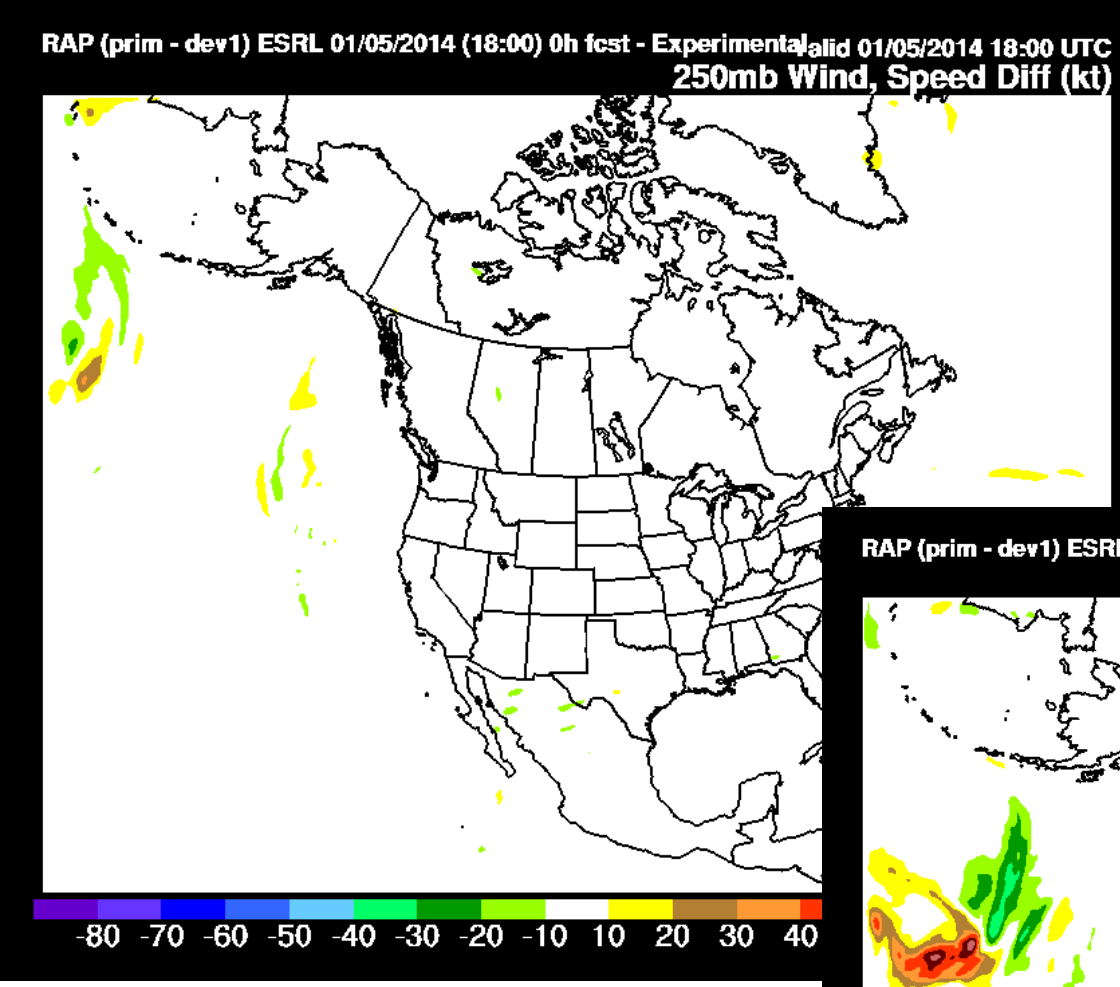
5 10 15 20 25 30 3

RAP-dev1-ESRL 01/06/2014 (18:00

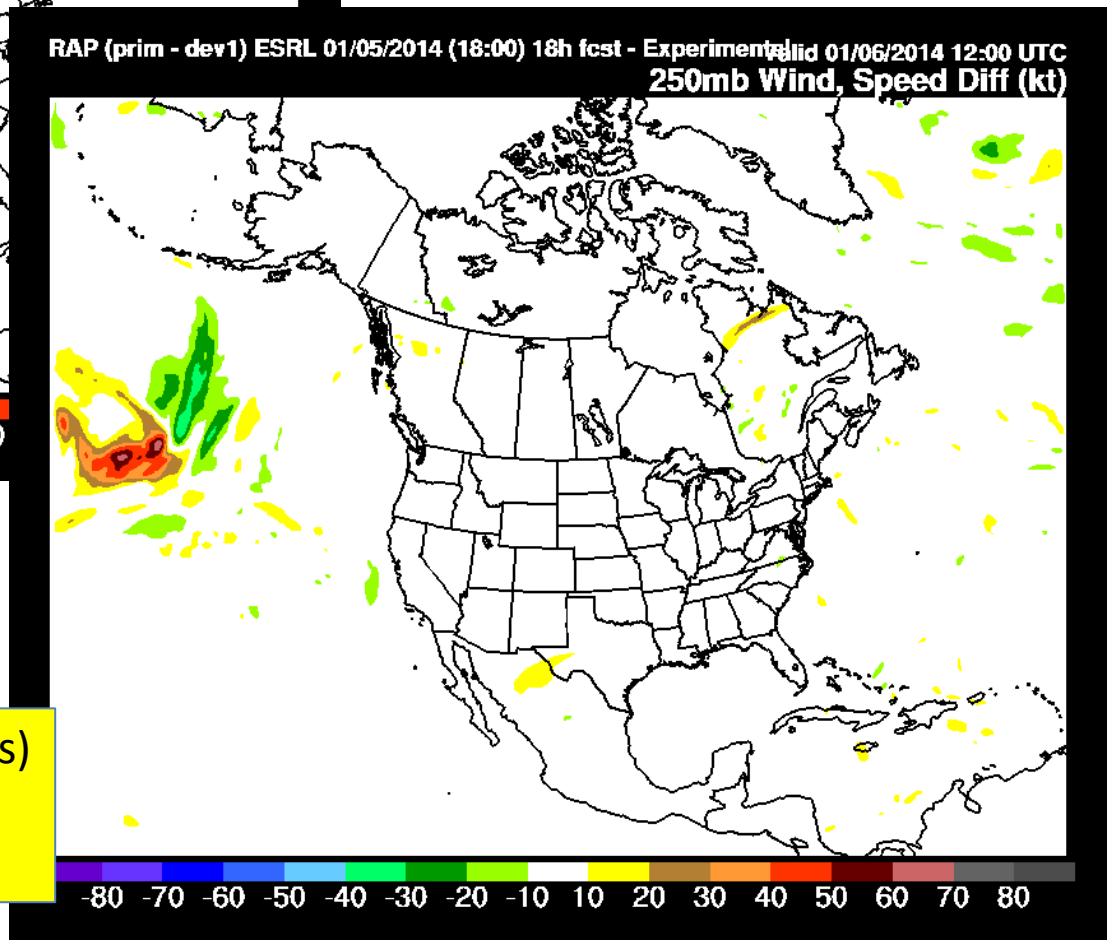


850 hPa wind
RAP-dev1 – 18h

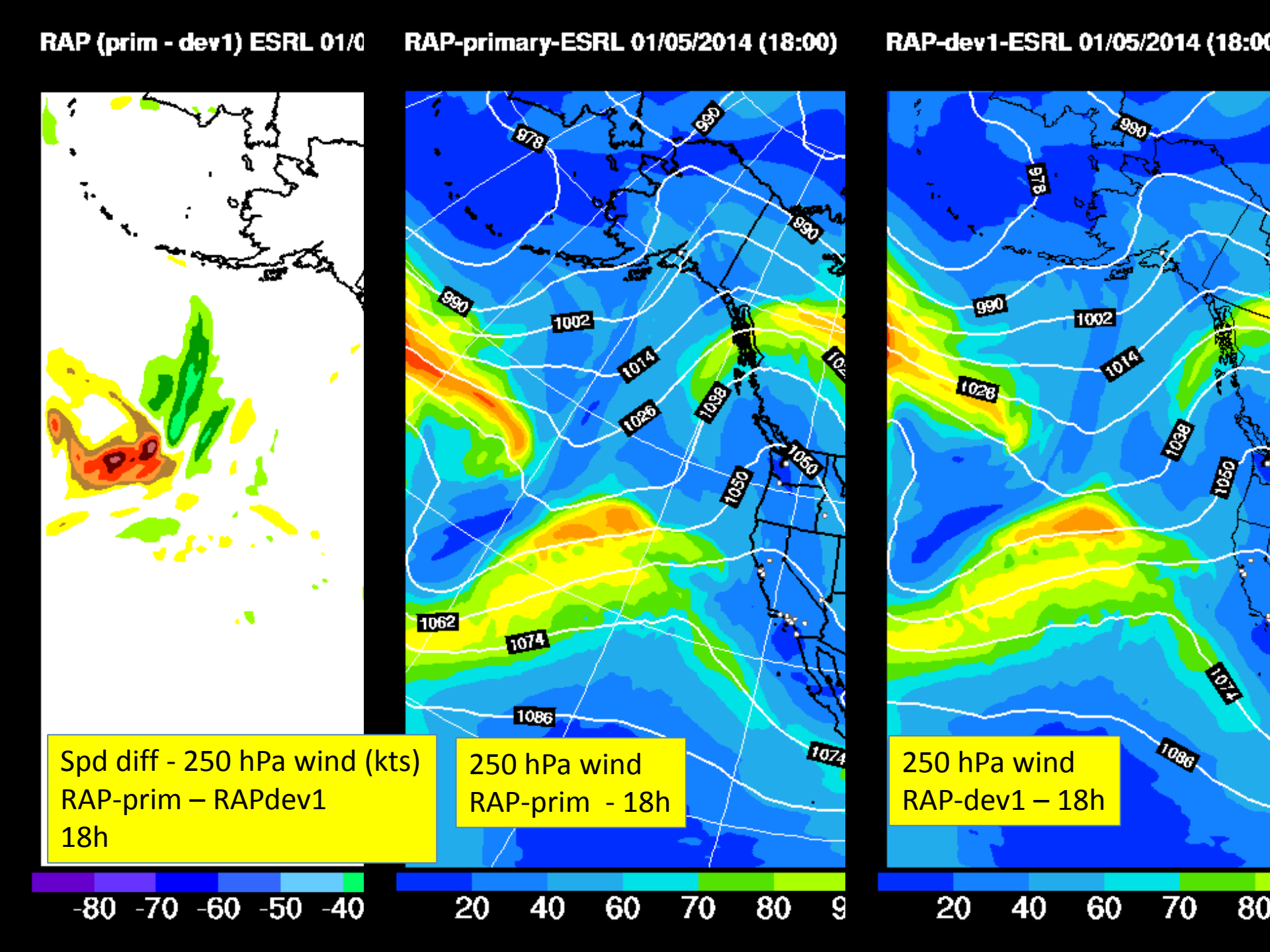
5 10 15 20 25 30 35



Spd diff - 250 hPa wind (kts)
RAP-prim – RAPdev1
0h



Spd diff - 250 hPa wind (kts)
RAP-prim – RAPdev1
18h


RAP (prim - dev1) ESRL 01/0
RAP-primary-ESRL 01/05/2014 (18:00)
RAP-dev1-ESRL 01/05/2014 (18:00
Spd diff - 250 hPa wind (kts)
RAP-prim – RAPdev1
18h
250 hPa wind
RAP-prim - 18h
250 hPa wind
RAP-dev1 – 18h
-80 -70 -60 -50 -40
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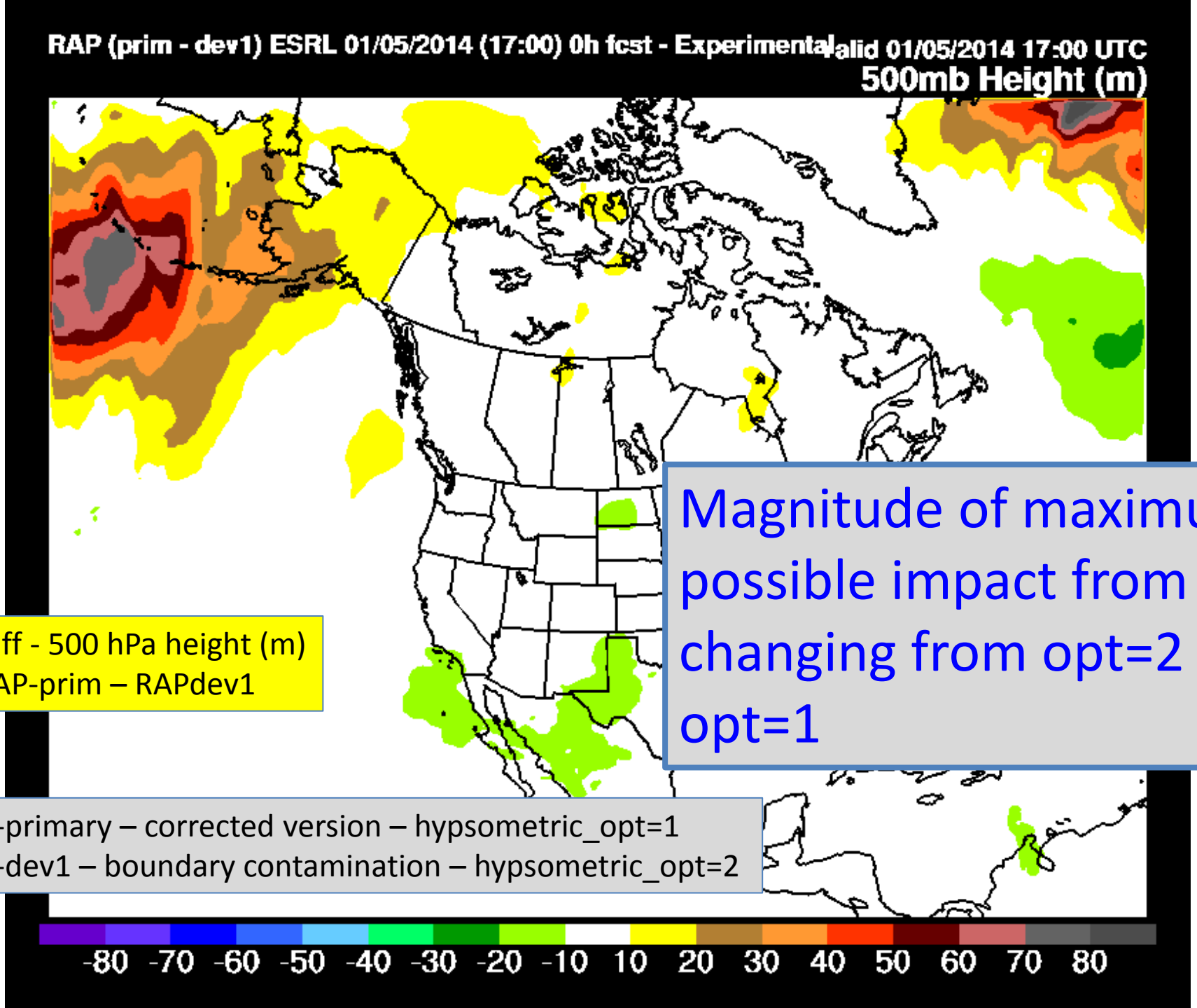
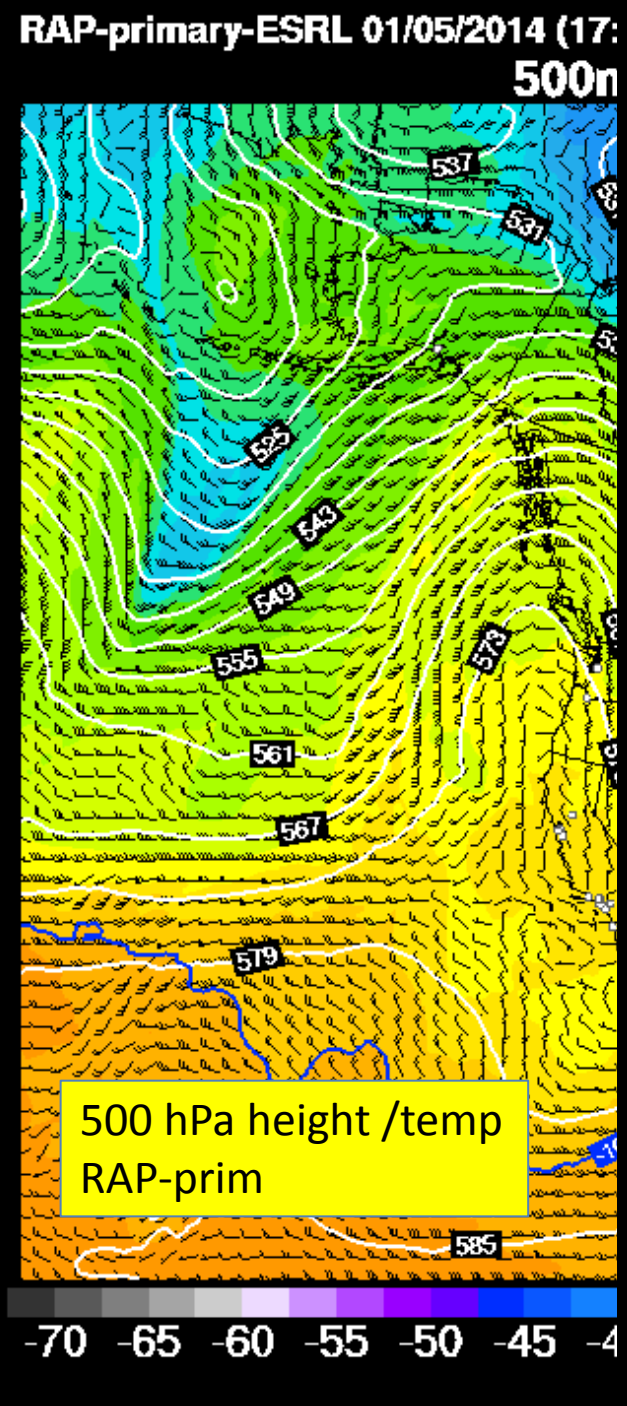
20 40 60 70 80


RAP (prim - dev1) ESRL 01/05/2014 (17:00) 0h fcst - Experimental
valid 01/05/2014 17:00 UTC
500mb Height (m)
Diff - 500 hPa height (m)
RAP-prim – RAPdev1
Magnitude of maximum possible impact from changing from opt=2 to opt=1
RAP-primary – corrected version – hypsometric_opt=1
RAP-dev1 – boundary contamination – hypsometric_opt=2
-80 -70 -60 -50 -40 -30 -20 -10 10 20 30 40 50 60 70 80


RAP-primary-ESRL 01/05/2014 (17:
500m
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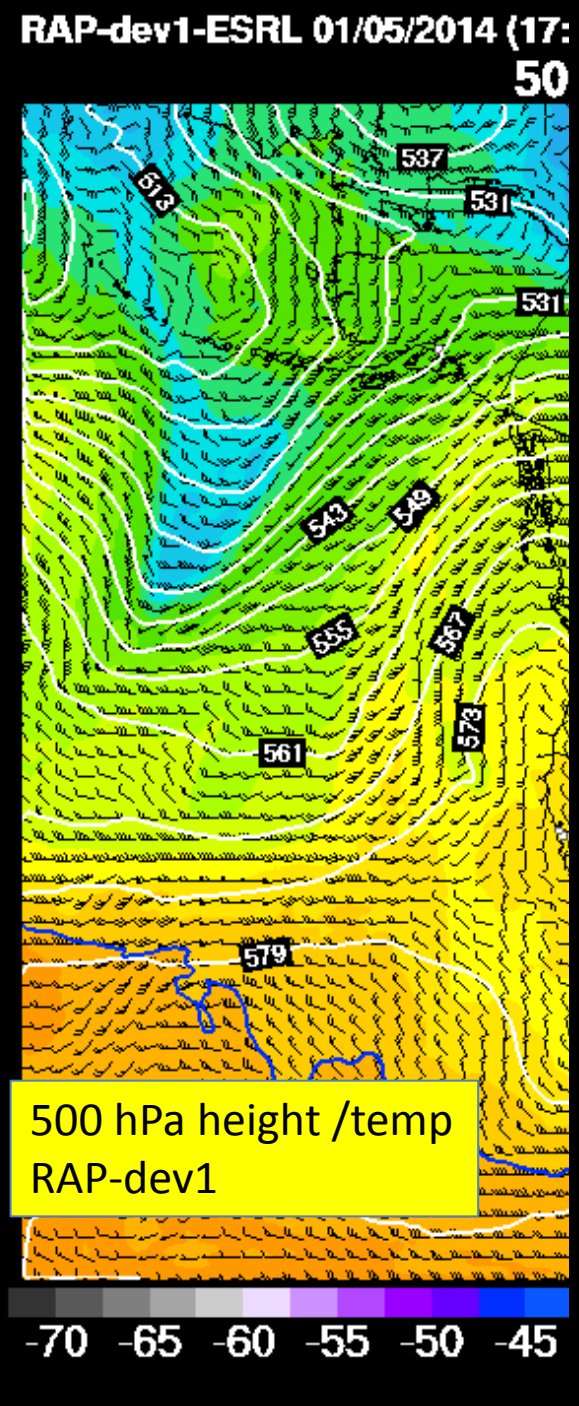
-70 -65 -60 -55 -50 -45 -4
500 hPa height /temp
RAP-prim


RAP-dev1-ESRL 01/05/2014 (17:
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500 hPa height /temp
RAP-dev1


RAP (prim - dev1) ESRL 01/05/
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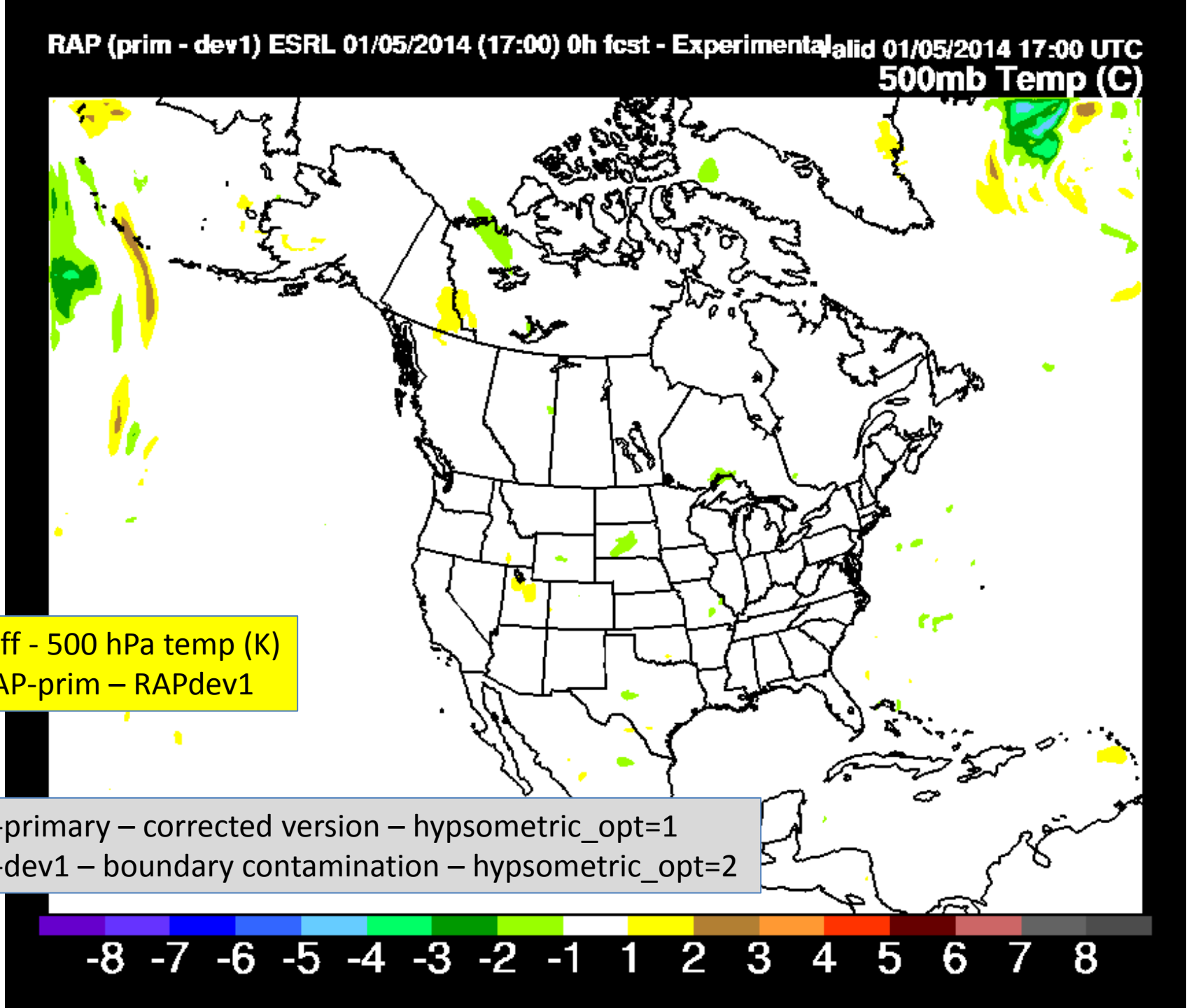
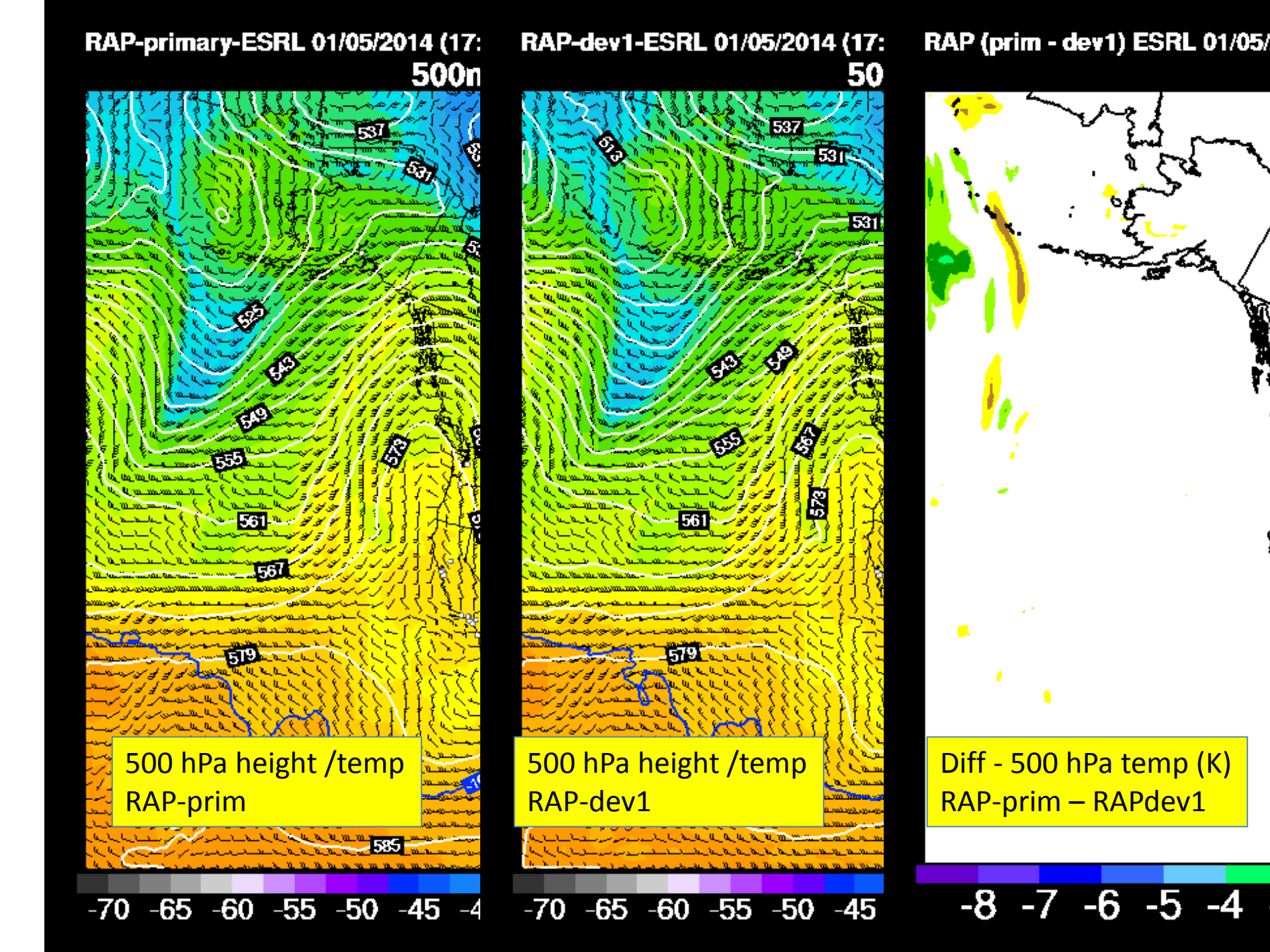
Diff - 500 hPa height (m)
RAP-prim – RAPdev1


RAP (prim - dev1) ESRL 01/05/2014 (17:00) 0h fcst - Experimental
Valid 01/05/2014 17:00 UTC
500mb Temp (C)
Diff - 500 hPa temp (K)
RAP-prim – RAPdev1
RAP-primary – corrected version – hypsometric_opt=1
RAP-dev1 – boundary contamination – hypsometric_opt=2
-8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8


RAP-primary-ESRL 01/05/2014 (17:
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-70 -65 -60 -55 -50 -45 -4
500 hPa height /temp
RAP-prim
RAP-dev1-ESRL 01/05/2014 (17:
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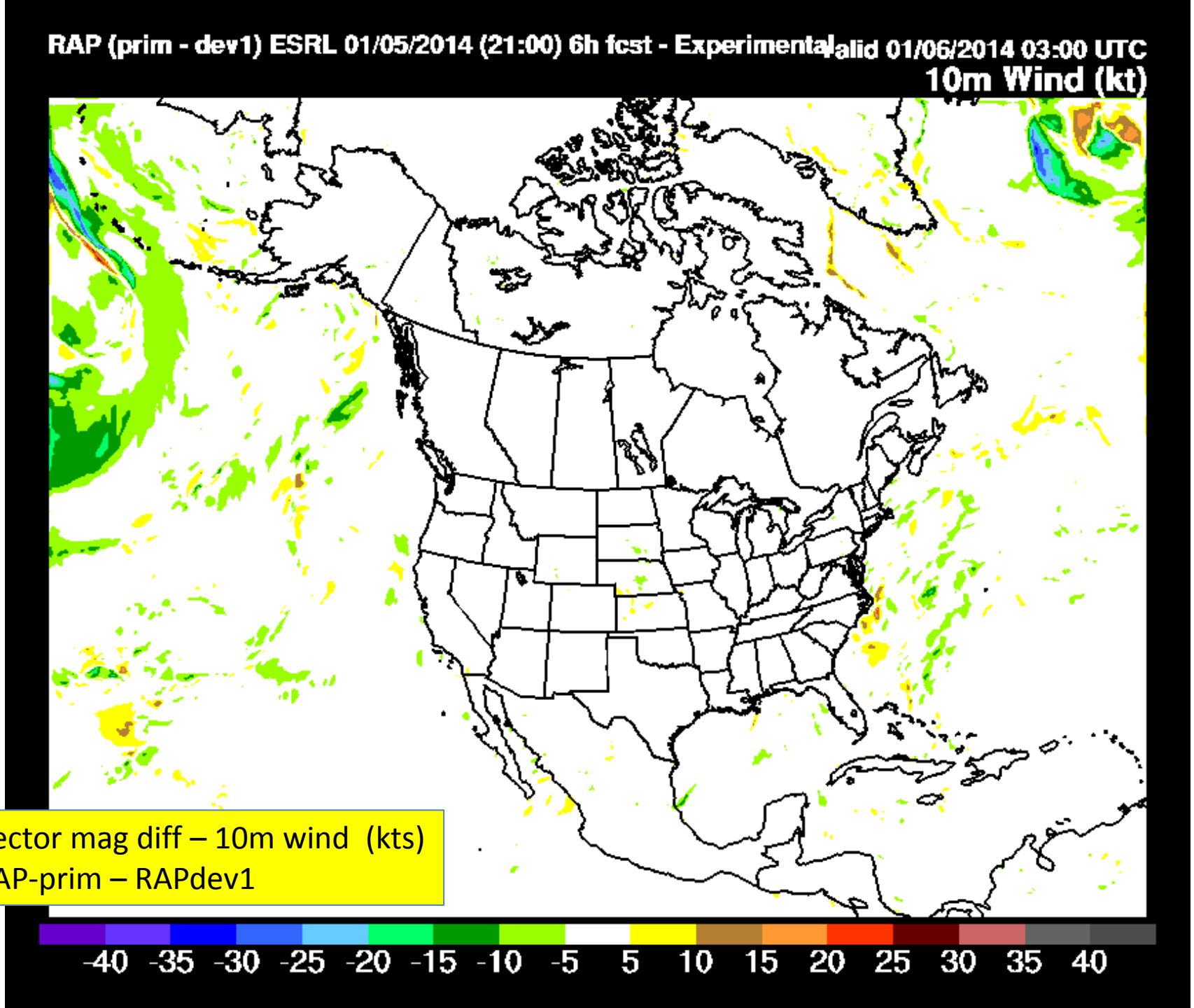
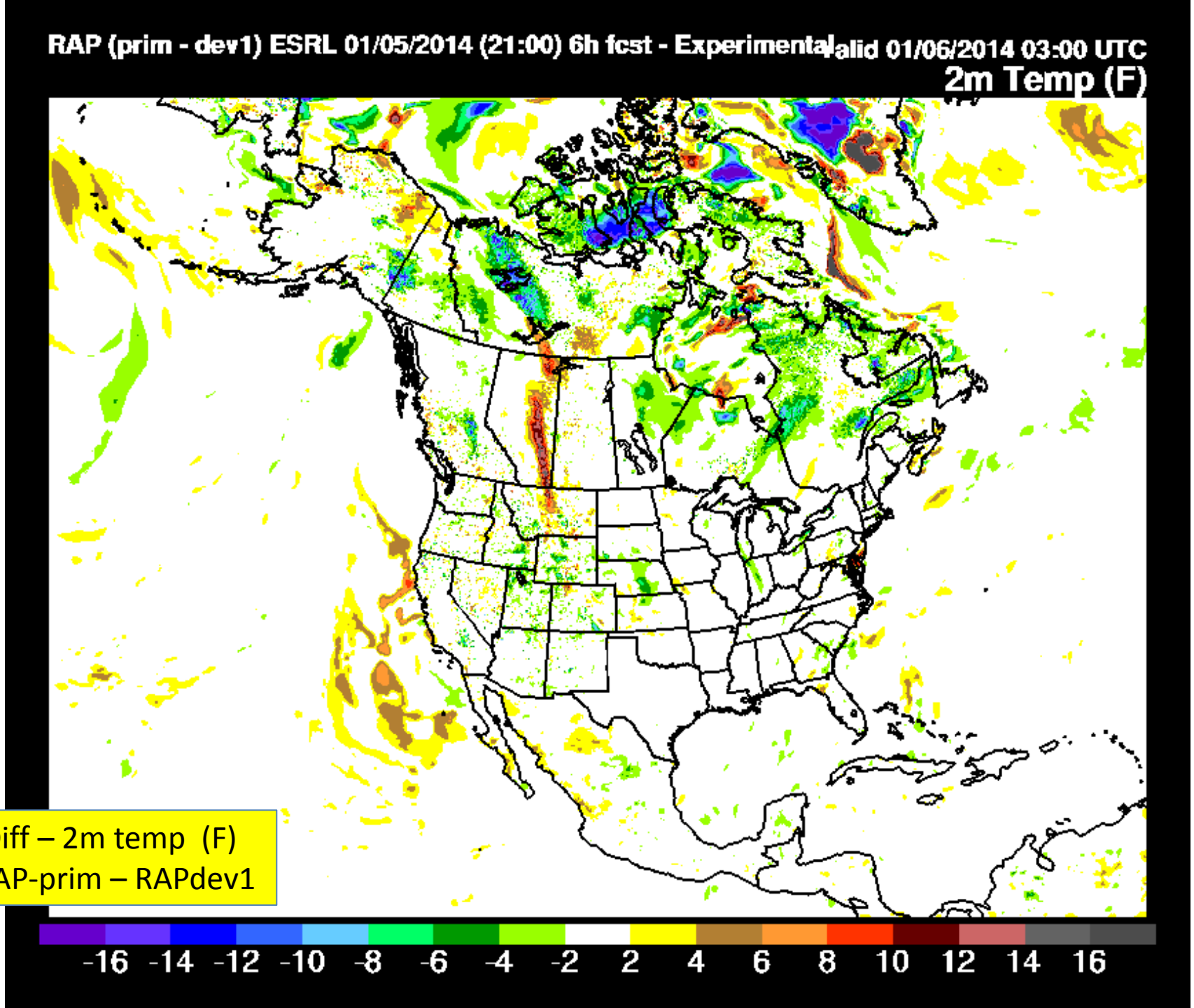
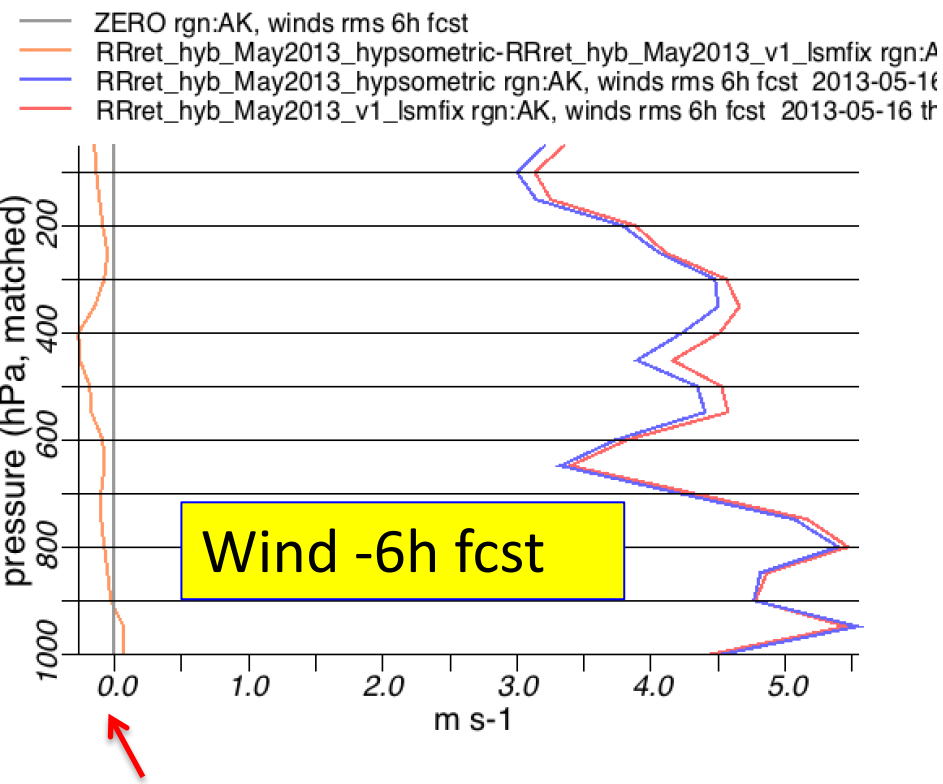
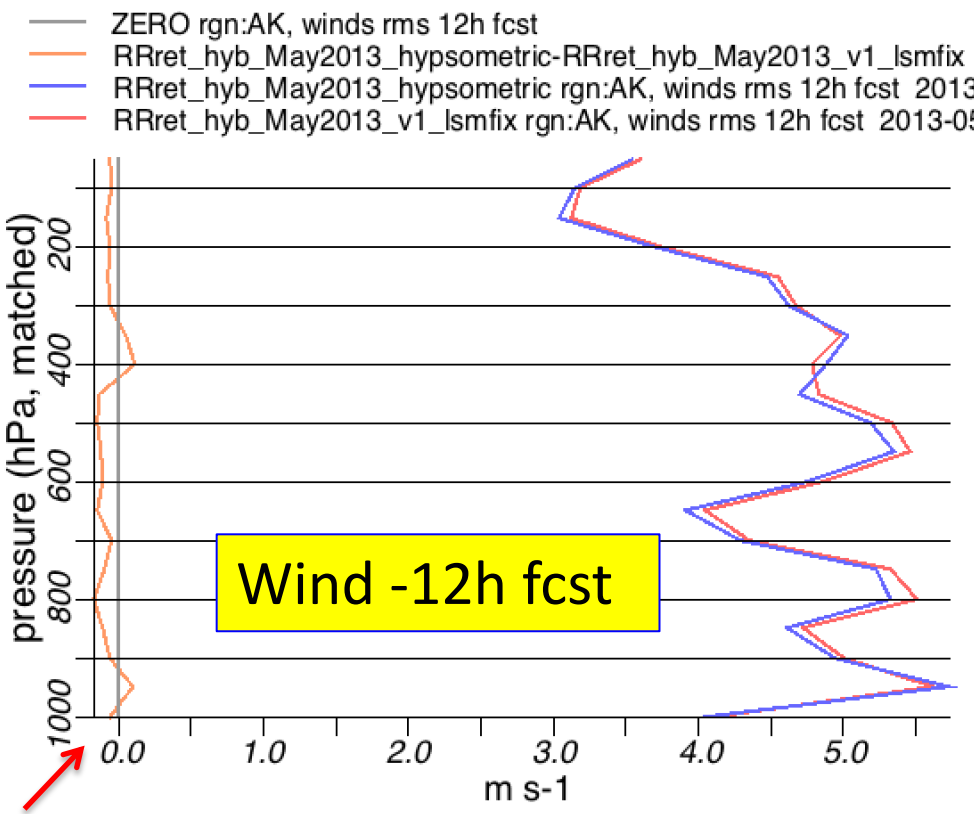
-70 -65 -60 -55 -50 -45
500 hPa height /temp
RAP-dev1
RAP (prim - dev1) ESRL 01/05/
-8 -7 -6 -5 -4
Diff - 500 hPa temp (K)
RAP-prim – RAPdev1



Vector mag diff – 10m wind (kts)
RAP-prim – RAPdev1


RAP (prim - dev1) ESRL 01/05/2014 (21:00) 6h fcst - Experimental
Valid 01/06/2014 03:00 UTC
2m Temp (F)
Diff – 2m temp (F)
RAP-prim – RAPdev1
-16 -14 -12 -10 -8 -6 -4 -2 2 4 6 8 10 12 14 16

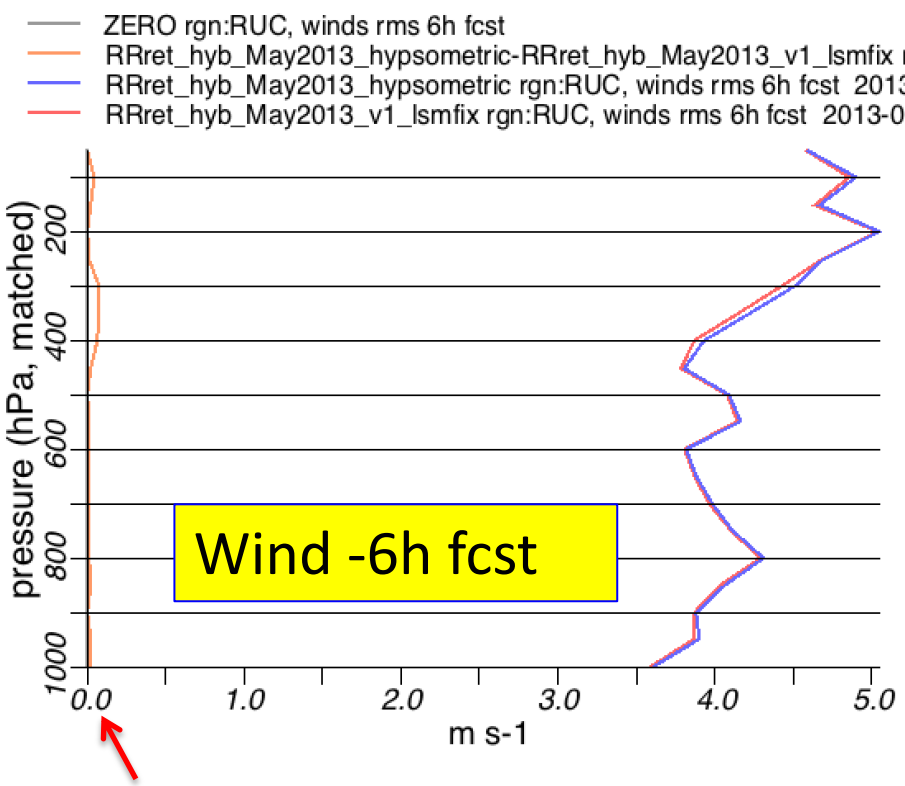


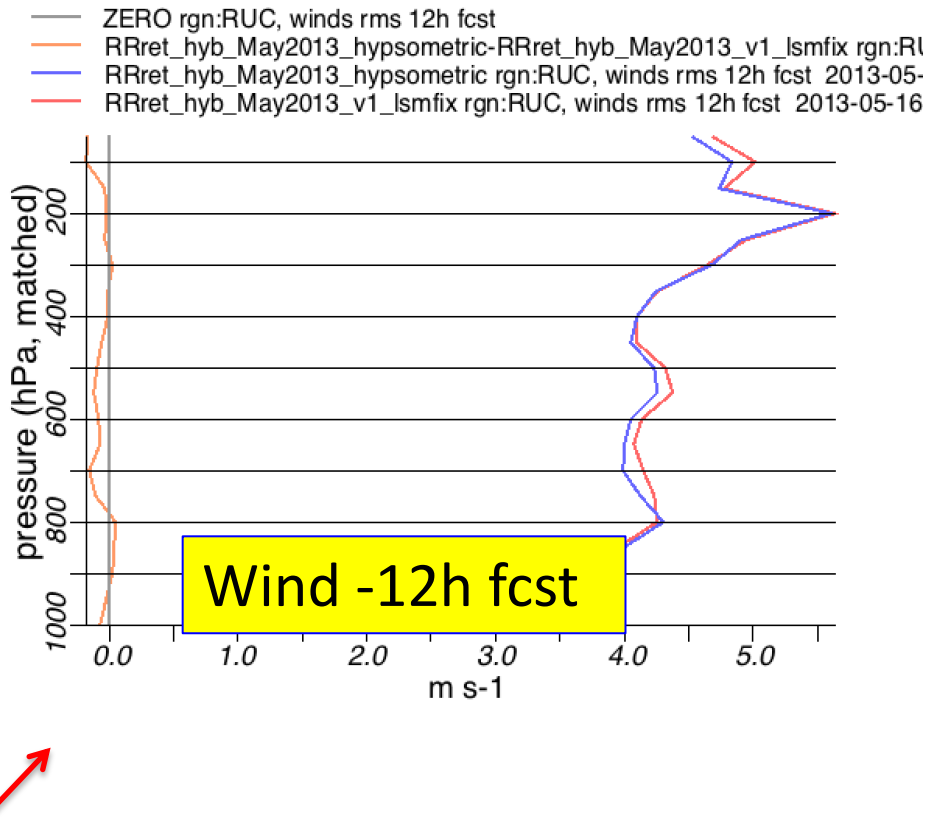


Improved with corrected hypsometric_opt=1

Warm-season retro – 15-19 May 2013
Alaska Region

Hypsometric_ opt=1(new)
v2 – opt=2 (old)

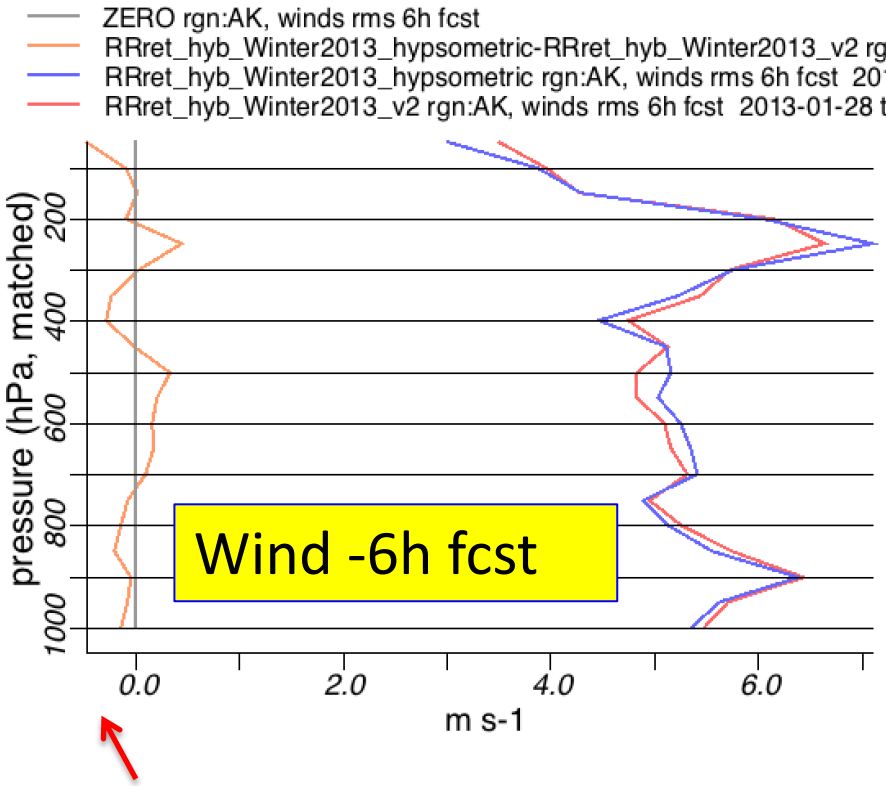


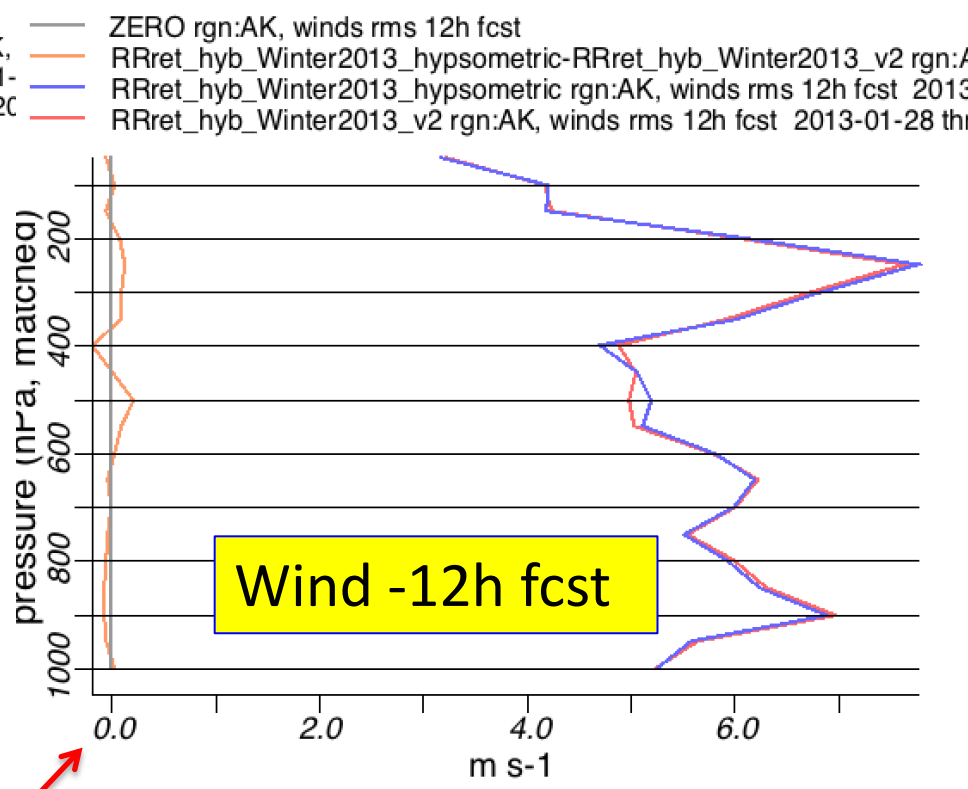


Very little difference with corrected hypsometric_opt=1

Warm-season retro – 15-19 May 2013
CONUS Region

hypsometric – opt=1(new)
v2 – opt=2 (old)

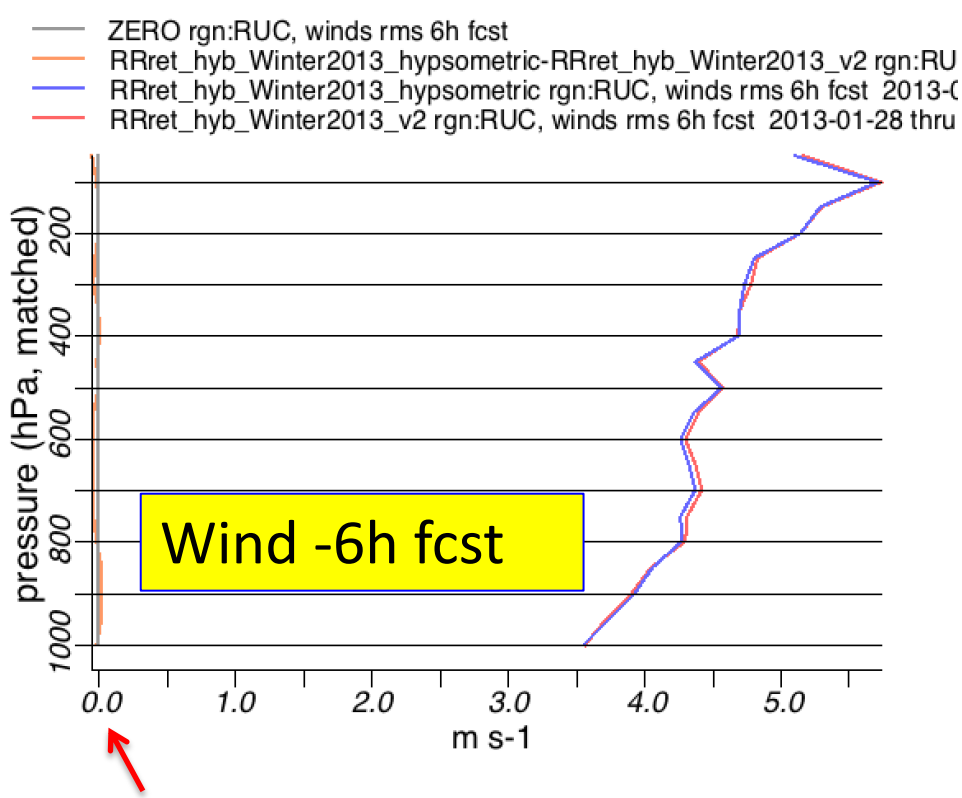


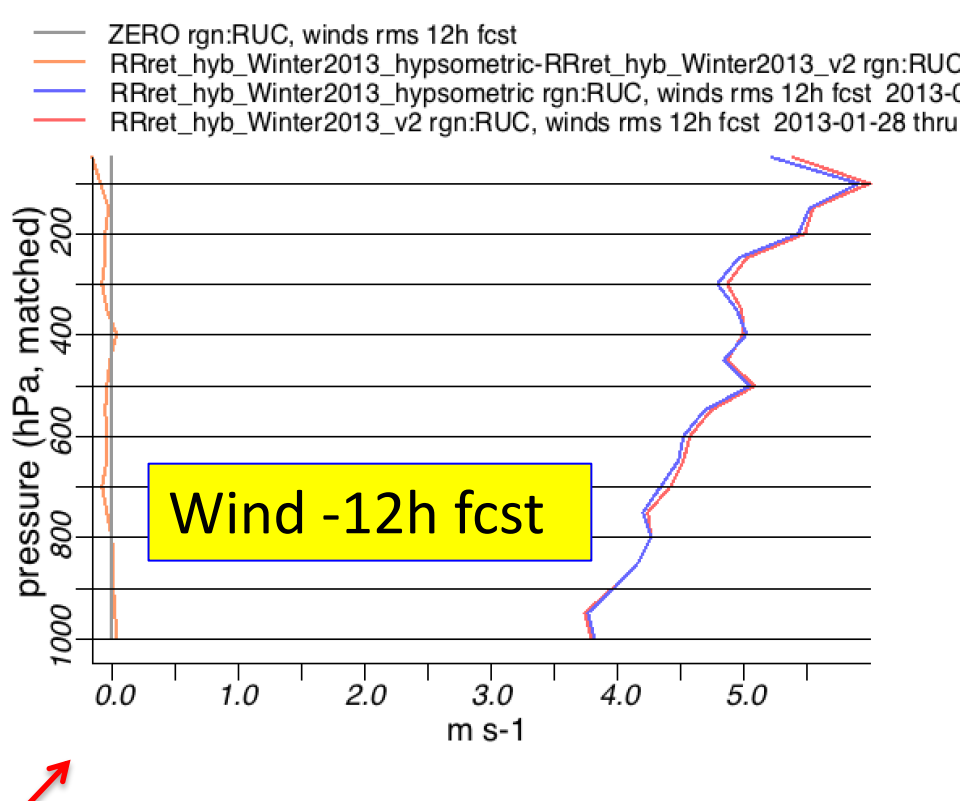


Skill overall similar with corrected hypsometric_opt=1

Cold-season retro – 28-30 Jan 2013
Alaska Region

Hypsometric_ opt=1(new)
v2 – opt=2 (old)





Skill extremely similar with corrected hypsometric_opt=1

Cold-season retro – 28-30 Jan 2013
CONUS Region

Hypsometric_ opt=1(new)
v2 – opt=2 (old)

From the 1/6 EMC-NCO Implementation Meeting

- Question arose as to whether the evaluation period needed to be restarted
- RAP team believes that, based on the results shown in the previous slides, all evaluations that were performed during December/early January are valid
- RAP team was asked to contact SPC/AWC to ask their approval to not restart their RAP evaluations, as bandwidth issues prevent them from pulling in parallel RAP and SREF grids simultaneously
- RAP team also asked to ask NWS Alaska Region to approve not restarting their evaluation, since they are closer to the boundaries
- Steve Silberberg (AWC), Steve Weiss (SPC), and Jim Nelson (Alaska Region) were sent many of these slides and were contacted personally to explain the recent change and its impacts; new graphics added to RAP web page for Alaska
  - all have agreed that they will require no further evaluation and have contacted Chris Magee with this information

Conclusions

- RAPv2 hypsometric_opt parameter change made by NCO to RAPv2-para on 30 Dec
- Change eliminates near-boundary height anomaly introduced by previous incorrect parameter. Change is solely in namelist parameter, no recompiling of code.
- NCAR subsequently found bug in hypsometric_opt=2 code, further justifying change to hypsometric_opt=1
- Solves NCO crash from 18z 26 Dec case
- Subsequent reruns of previous Greenland and Venezuela/Colombia RAPv2 crash cases with hypsometric_opt=1 were all successful without any terrain elevation changes.
- Difference fields with old/new values show differences over ocean (new appears better) and very small to no differences over CONUS
- GSD cold-season and warm-season retro with modification showing little difference over CONUS, some improvement over AK
- GSD has already started discussions with NCAR to improve process for GSD/EMC/NCAR review of main numerical changes to WRF in its releases.
- We ask for the approval of the EMC director and then NCO to not require further field evaluation and to retroactively reset the 30-day crash-free period to begin on 12/30/13